Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City

First Progress Report: Deliverable 2.1

Prepared by LOGIOS

for the United Nations Industrial Development Organization and the Climate Technology Centre & Network

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1. Introduction

A critical step toward the evaluation and monitoring of the City of Panama Metro Bus public transport system is to obtain realistic characterizations of the operation of buses in the system. This report focuses on the process of data collection that was carried out to arrive at such characterizations and a discussion of the results.

The first step in the process of data collection is the selection of bus routes that are representative of the road infrastructure and driving conditions of the buses providing service in Ciudad de Panama and Distrito San Miguelito. In consultation with the local public transport operator — MiBus — five of their service routes were selected. The technical assistance involved also the evaluation of the ongoing electric bus pilot project that is running along a designated route in the *Casco Antiguo* of Ciudad de Panama, and for this reason, this route was also evaluated. The selection criteria were the following:

- *Road infrastructure:* motorways, trunk avenues, distributors and internal streets.
- *Driving patterns:* Stop&Go, Saturated and Free-flow operation related to peak hour traffic on main avenues and distributors.
- *Population density:* zones of the city with different flows of pedestrians, public transport users and drivers.
- *Altitude:* flat, ascending and descending routes with varying slope.

Table 1. Classification of the selected routes according to the selection criteria: Road Infrastructure, driving patterns, population density and altitude.

Name	Road infrastructure	Driving patterns	Population density	Slope
EBUS	Internal streets	Stop&Go	High – Downtown	Medium
CSFAL	Distributor – Trunk Avenue	Saturated	Medium	Medium - High
SIRTC	Distributor	Stop & Go	Highly populated boroughs	High
DOMAL	Trunk Avenue	Stop&Go – Saturated – Free Flow [1]	Medium	Medium
TOSAL	Trunk Avenue w/ Exclusive Lane	Saturated – Free Flow [1]	Medium	Low
VECMC	Distributor – Trunk Avenue	Saturated	Highly populated boroughs	Medium - High
CHOMA	Distributor – Trunk Avenue	Stop&Go – Saturated	Highly populated boroughs	Medium - High
MAMPK	Distributor – Trunk Avenue	Stop&Go – Saturated	High – Downtown	Medium

In addition to the 6 predefined routes, two extra routes were added to the study. These were selected based on the preliminary results obtained from the gathered data on the 6 established bus operations, whilst having in mind the technical characteristics of alternative bus technologies such as electric buses.

Figure 1 shows a map of the city of Panama and highlights the eight selected bus service routes. Table 1 and Table 2 display their main characteristics. These are followed by a brief description of each of them.

[1] Depending on the hour of the day

Figure 1. Map of the bus line routes selected collaboratively by MiBus and LOGIOS. These lines represent the different route infrastructures and driving conditions existing on the city. A detail of the pilot project bus route is included in the lower right corner.

Table 2. Characteristics of the selected routes. Route names are indicated in the colour corresponding to their trips, shown in the figure above.

Name	Concept	Route	Length	Daily distance
EBUS	Circular	5 de Mayo – Casco Antiguo	4.8 km	75 km
CSFAL	Circular	Albrook-Av Omar Torrijos-Ciudad del Saber	18 km	400 km
SIRTC	Circular	Estacion San Isidro-Est Torrijos Carter	14 km	230 km
DOMAL	Return	La Doña-Tumba Muerto-Albrook	67 km	440 km
TOSAL	Return	Tocumen-Corredor Sur-Albrook	73 km	600 km
VECMC	Return	Veranillo-Via Israel/Cinta Costera-M. de Mariscos	34 km	240 km
CHOMA	Circular	P Amelia Denis-Est. Marañon-Chorrillo	17 km	170 km
MAMPK	Circular	Est. Marañon-Tumba Muerto-Av La Paz-Transistmica	8 km	230 km

5 de Mayo – Casco Antiguo (EBUS)

This is the bus route that was designated for the electric bus pilot in the Casco Antiguo. It is 4.8 kilometers long with eight stops. It goes from 5 de Mayo station in the city Centre, to the Casco Antiguo, forming a loop along its main streets. The bus runs on narrow single-lane streets, where pedestrian traffic is significant. There are important slopes in a few parts of the route.

Albrook-Avenida Omar Torrijos-Ciudad del Saber (CSFAL)

Albrook is the main bus terminal in Ciudad de Panama. This circular route is 17 kilometers long, starts in Albrook and runs through Ciudad del Saber and the Clayton district. These are neighborhoods in the outskirts of the city, next to the Panama Canal. Half of the route is done on one-lane avenues, while the other half is done on Avenida Omar Torrijos Herrera, which is a two-lane avenue. The whole circuit is highly sensible to traffic congestion on peak hours, the first section is mainly affected by lacking road infrastructure and the second due to the proximity to Albrook station, a neuralgic transport hub of Panama City. Furthermore, the route has an aggressive slope profile.

Estacion San Isidro-Estacion Torrijos Carter (SIRTC)
This 14-kilometer circular route is in the center of Distrito San Miguelito. It starts at San Isidro Station and goes to the north east of the city through San Isidro, Santa Librada and Torrijos Carter neighborhoods. Buses servicing this route operate on different road infrastructures including narrow streets and one-lane avenues with steep slopes. Traffic conditions vary slightly over the day, with peak periods of demand during the morning, midday and afternoon, as in most of the other routes.

La Doña-Tumba Muerto-Albrook (DOMAL)
This is a relatively long route, covering 67 kilometers, and travels along one of the main arteries of the city, first on the Tumba Muerto Avenue and then through Domingo Diaz Avenue (currently below works for the Metro Line 2). Traffic is heavy in the direction to Albrook in the morning and in direction to La Doña in the afternoon. This results in stop-and-go driving conditions along most of the way.

Tocumen-Corredor Sur-Albrook (TOSAL)
This is the connection between Tocumen, the international airport, and Albrook, the most important transport hub of Panama City. The route runs along the coastline, by Corredor Sur Highway and therefore has low elevation variation. Moreover, there is an exclusive bus lane which extends over 50% of the route distance, which improves the flow of the system.

Veranillo-Via Israel/Cinta Costera-Mercado de Mariscos (VECMC)
This is a relatively-short route of only 17 kilometers between terminals but has diverse characteristics. It starts of in narrow one-lane avenues in the residential neighborhoods of the San Miguelito district, traveling from Los Andes Station to Panama Viejo. Considerable slopes are observed around the Los Andes station. Then the route travels along the coastal Avenida Balboa. Traffic conditions vary significantly. In the morning rush hour there is high traffic in direction to Mercado de Mariscos, and in the afternoon, in the direction to Veranillo.

P Amelia Denis-Est. Marañon-Chorrillo-Circular (CHOMA) and Est. Marañon-Tumba Muerto-Av La Paz-Transistmica-Circular (MAMPK)
These two routes were added to the study based on the preliminary evaluation of the data collected on the other routes. CHOMA and MAMPK are two circular centric routes. The first one goes from Marañon terminal (near 5 de Mayo station) to El Chorrillo neighborhood, through narrow streets and densely populated areas. MAMPK, goes through two of the main arteries in the city, Via España and Transisimica Avenue, both of which have three traffic lanes each way. Traffic congestion is prevalent in the city center during most of the day.

2. Methodology

Following the selection of a representative sample of service routes, the next step is to obtain a realistic characterization of the operational cycles of these routes. Such characterization involves primarily the profiles of vehicle three-dimensional position over time, from which velocity, acceleration (inertial and gravitational) can be derived. Some studies have used ad-hoc assumptions to define these profiles, and most studies have neglected the measurement of road grade. There is however no real substitute to on field measurements of operational conditions to determine these accurately.

For this technical assistance, LOGIOS used a global positioning system (GPS) on board of buses in service, to collect the needed data and constructed driving cycles that are directly associated with real operations along each of the selected routes. This is a laborious, though fundamental step to provide a solid foundation for the analysis that follows. The methodology used to replicate the operation of service routes is shown in **Figure 2**.

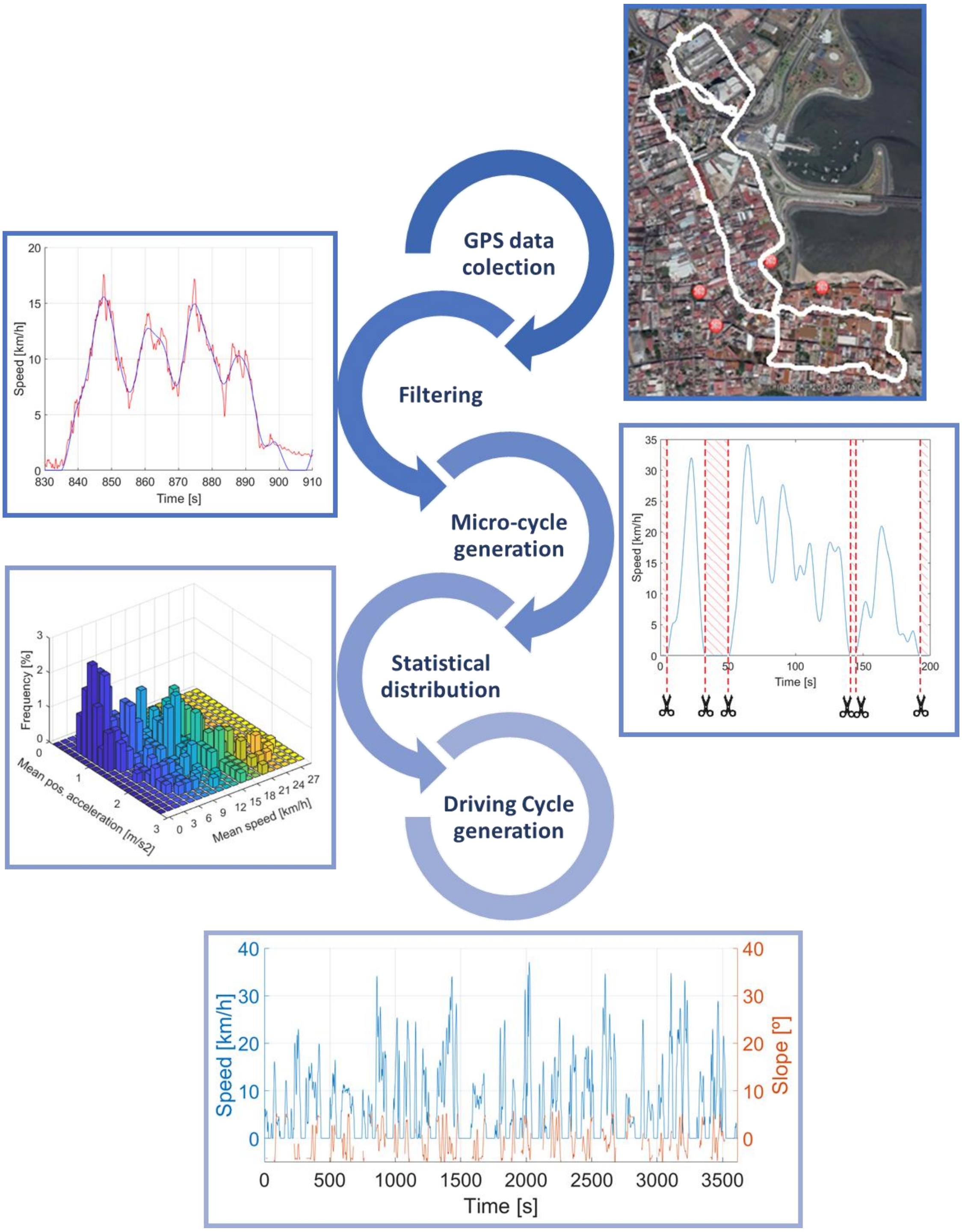


Figure 2 GPS Data collection and processing methodology

The data collected via GPS and is then processed with filters to remove any spurious or erroneous data points. After this the data is segmented into micro-cycles, which we define as driving events spanning from one stop position to the next. the individual micro-cycles are then categorized based on their mean speed and mean acceleration to establish the statistical distribution of the data pool. Finally, using all of the above, a representative driving cycle of a given operation can be created.

2.1 GPS data collection

Figure 3. Geo coordinates plot of the BYD e-bus route, with visualization of the distribution of speeds along the route.

Figure 4. Geo coordinates plot of the BYD e-bus route, with visualization of the number of satellites available to support the GPS along the route.

To collect the data of the different bus routes operations, LOGIOS used an AIM - SOLO 2 DL GPS data logger unit. This is a high precision tracking device, with the capability of recording three-dimensional geographical location (latitude, longitude, and altitude), speed (Figure 3), acceleration, slope, and the number of satellites available for each measurement, with a frequency of one tenth of a second. As shown on Figure 4, the number of available satellites can be used, when needed, to assess the precision of the recorded data and see what sections of a given route require more attention.

LOGIOS collected more than 85 hours of data on the selected routes, covering over 400 kilometers, in a period of four weeks, We developed a data collection plan to ensure that sufficient usable data was collected evenly over the day and days of the week. An example of the collection process throughout a week can be seen on Figure 5. (The complete schedule is displayed in an Annex at the end of the document).

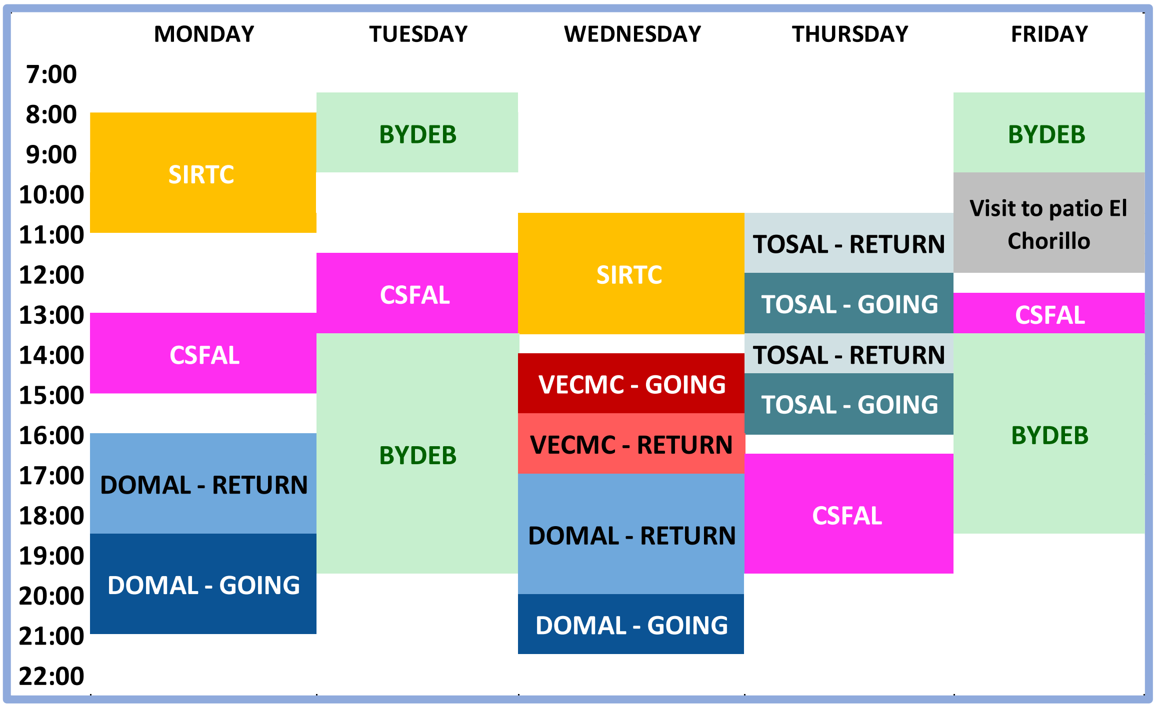


Figure 5. Example of the data collection chronogram of the different selected routes throughout one of the weeks of LOGIOS visit to Panama City.

To complement the data collection, LOGIOS spent numerous hours on the ground visiting key locations of the city´s public transport system: bus terminals, MiBus depots or *patios*, intermodal hubs (such as connections with metro stations), trip attraction centers (such as touristic areas), etc. Some of this fieldwork can be seen on Figure 6 and Figure 7. Visiting public transport hubs, bus terminals and other relevant locations of the systems operation is crucial to have a true understanding of how the latter operates. For example, in one of our visits to the bus terminal operation headquarters, we found out that buses can start their operation on one route and then return on a different one. This, which sounds as something very trivial, would have serious implications when establishing an electric bus penetration strategy, given that due to their limited range, the latter are less flexible to changes in their operation then conventional diesel buses.

Figure 6. Some of the fieldwork of LOGIOS team, during its visit to Panama City. The top image shows Gustavo Collantes (LOGIOS's CEO) exposition during an event organized by UN Environment in Panama to launch the national electromobility strategy. The middle and bottom images show LOGIOS's Analyst Tomas Seguí's visit to Patio El Chorrillo, as part of his field work over a period of seven weeks in Panama.

Figure 7. Images of Albrook bus terminal (top and middle) and Bahía C station (bottom) visited during fieldwork conducted by the LOGIOS team in Panama City.

2.2 Data Filtering

The data collected with GPS equipment must be filtered for two key reasons: a) to eliminate defects, such as signal loss, measurement error, etc.; and b) to eliminate signal noise and produce smoother operation profiles that are more representative of real inertial effects. The filtering process consists of six conditioning steps that aim to replicate the real cycle. These are:

- Remove possible duplicated records, negative speed values, or negative differential time steps;
- Eliminate records where the number of satellites available was less than five;
- Remove outlying high/low speed values;
- Remove false zero-speed records;
- Remove zero-speed signal drift when vehicle is stopped;
- Amend gaps in recorded data.

Figure 8 shows an example of GPS data collected on board the electric bus before and after the filtering process. It also shows the number of satellites available at any given point during the time sample. Once processed, the information enables the analysis and understanding of the operating conditions of a specific bus route and that of the overall system. Based on the analysis requirements the data pool can be used to evaluate specific events or used to have a statistic overview of the entire system

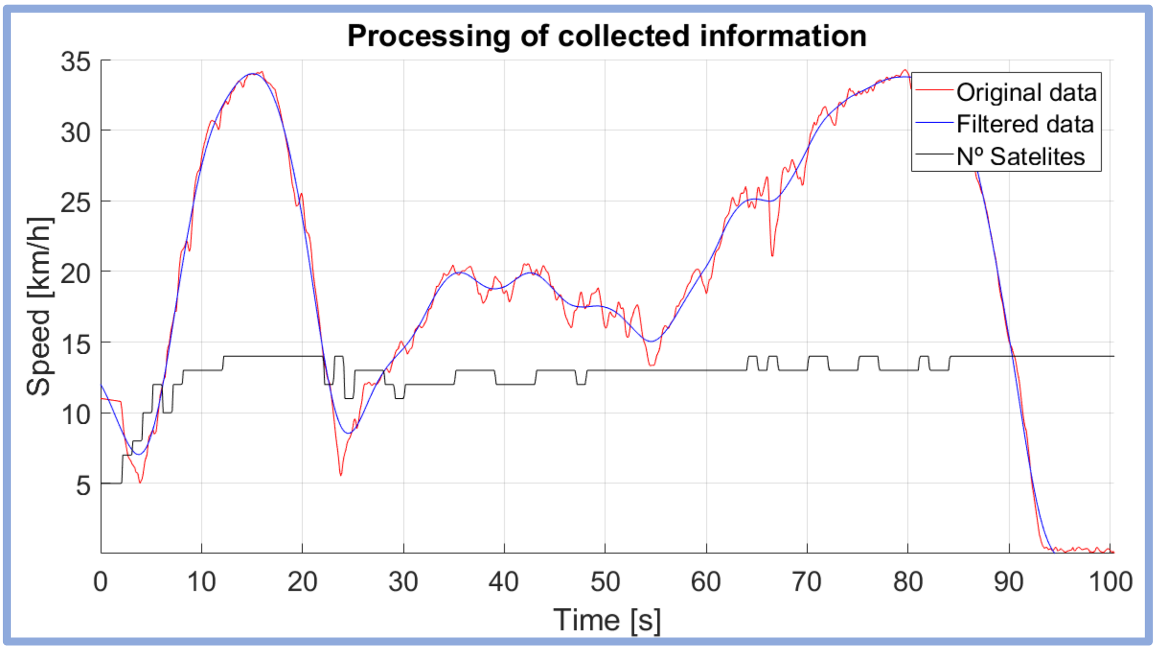


Figure 8 Example of data filtering process results.

2.3 Micro-cycles generation and conditioning

Once the data pool has been conditioned, it is then divided into *micro-cycles*. As mentioned above, these are defined as individual driving events between subsequent stops.

The reason for discretizing the data pool is that a typical urban bus operation involves fixed bus stops, congestion stops and traffic signal stops, all of which generate the characteristic *stop & go* driving patterns. Therefore, discretizing the data allows separating and categorizing the information to then construct driving cycles using a combination of micro-cycles that best represent the parameters of a given data pool.

Figure 9 shows how a speed profile dataset is divided into micro-cycles. Each micro-cycle has a characteristic mean speed, mean acceleration, and road grade (topographical slope), as well as time duration. All of these are contrasted to the characteristic parameters of the data pool of the pertinent route to select a combination of micro-cycles and construct a representative driving pattern for that route. This cycle can then be used to analyze a given route operation.

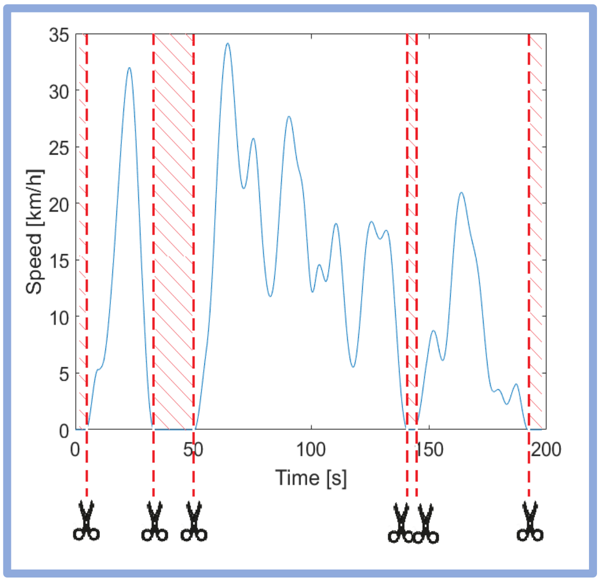


Figure 9. Micro-cycle sectioning

2.4 Micro cycle statistical distribution

As mentioned above, each one of the micro-cycles has a characteristic mean velocity and mean acceleration. The aggregate can be used to obtain a characteristic statistical distribution of the data pool for each route, or for the entire system. An example of this is shown in the left image of **Figure 10** where each point represents the mean speed, slope and acceleration of a single micro-cycle.

As it can be seen in the right image of **Figure 10**, the distribution allows determining the frequency of occurrence of a micro-cycle with certain mean parameters. This frequency map is respected when building the final driving cycle.

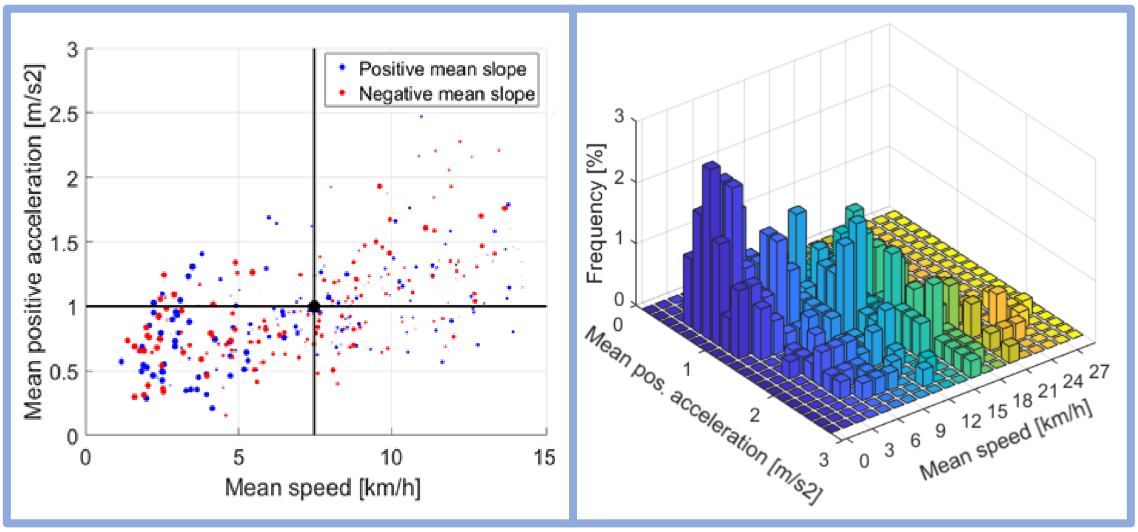


Figure 10. Micro-cycles statistical distribution and frequency of occurrence for EBUS data set classified by mean speed and mean positive acceleration. The dot size represents the mean slope magnitude of each data.

The above methodology allows to build representative driving cycle by combining a number of micro-cycles that match the statistical distribution of a given data pool. This means that micro-cycles with all low to high mean speeds, accelerations and slopes are picked from the original data.

The last ensures that all driving conditions found in the original data pool are reflected in the final driving cycle. This is essential to arrive at realistic estimations of energy consumption and overall vehicle efficiency, as well as assessing the vehicle configuration that could satisfactorily serve a given route under real operating conditions.

2.5 Driving cycles generation

Using the micro-cycle data pool and the dataset statistical distribution, a representative driving cycle can be generated for each of the bus routes that are being evaluated. **Figure 11** shows the successive steps followed to create a representative driving cycle. An algorithm executes an iterative process under which micro-cycles are selected and compared to the statistical distribution of the data pool, then an idle time is added until the final driving cycle is generated.

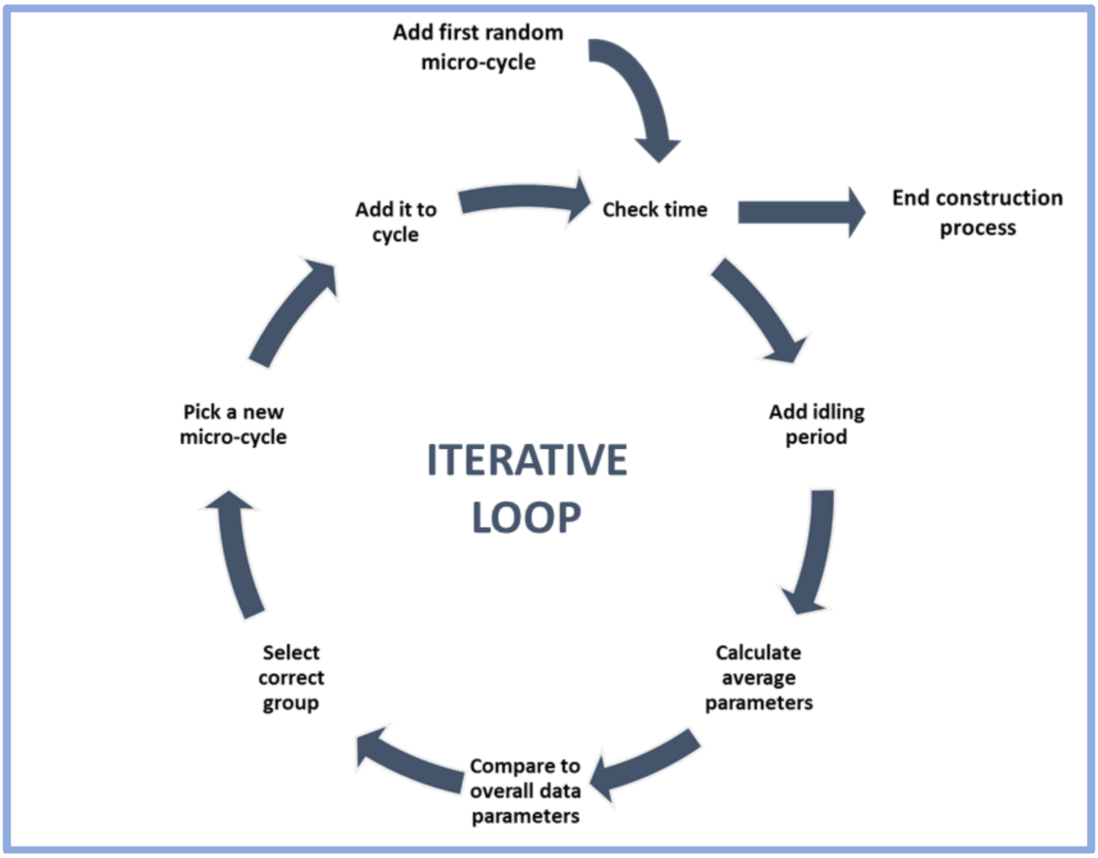


Figure 11. Steps of the algorithm used to construct driving cycles.

The final construction results in a stochastic cycle with main parameters, such as mean speed, mean positive acceleration, and mean slope, equivalent to those of the overall data pool. The frequency of occurrence of the micro-cycle dataset is reflected in the constructed driving cycle, to account for typical as well as extreme cases.

This process was followed for each of the routes that were proposed in order to construct a set of driving cycles. The results are summarized in the section below.

3. Results

Using the above presented methodology, a thrall analysis of all the monitored bus routes was performed. Based on the recorded information, the key characteristics of each route are detailed in **Table 3** and **Table 4**. The driving cycles and the additional information collected throughout the field work scope of this project are crucial inputs to undertake the tasks specified in Outputs 2.2 and 2.3.

Table 3. Preliminary information of the data collected for each of the round routes.

	EBUS	CSFAL	SIRTC
Trip	Round	Round	Round
Mean Speed [km/h]	7.3	22	10.5
Mean Pos. Accel. [m/s²]	1	1.4	1.2
Mean Pos. Slope [°]	3.5	2.5	4.2
Mean Neg. Slope [°]	-3	-3	-3.9
Idle Time	34%	22%	32%
Useful hours of data	11	13.5	12
Useful kilometers	80.3	297	126

Table 4 Preliminary information of the data collected for each of the two-way routes.

	DOMAL		TOSAL		VECMC	
Trip	One way	Return	One way	Return	One way	Return
Mean Speed [km/h]	15.8	11.4	32.8	25.5	12.7	12.9
Mean Pos. Accel. [m/s²]	1.3	1.1	1.4	1.3	1.3	1.2
Mean Pos. Slope [°]	3.2	3.3	2.5	4	4.3	5.2
Mean Neg. Slope [°]	-3.2	-3.5	-2.4	-3	-5.2	-4.5
Idle Time	27%	33%	16%	22%	27%	25%
Useful hours of data	7	10	7	9	8	7
Useful kilometers	110.6	114	229.6	229.5	101.6	90.3

Results show that the operating conditions of the different bus lines are strongly related to both road infrastructure and traffic conditions, being the latter, as expected, dependent on the time of the day. Mean speed, positive acceleration, as well as idle time percentage are within the normal range that could be expected for a city with the traffic conditions of Panama. However, the different routes show very distinctive profiles. Mean speeds range from 7 to 33 km/h, positive accelerations from 1 to 1.5 m/s², and idling times from 15% to 35%. Driving cycles with these characteristics will result in different energy consumptions. Mean positive and negative slope values are found to be high in certain parts of the city. This is expected to have a considerable impact on the electric bus energy consumption.

To show the kind of information and analysis that can be attained with the presented methodology, this section presents and discusses the resulting driving cycles of the EBUS and TOSAL routes. These present very different characteristics of road infrastructure, traffic intensity, environmental conditions and context and therefore can be used to discuss and analyze the implications of the latter on the resulting bus operation.

The representative driving cycles of the two selected operations are shown in **Figure 12** and **Figure 13**, respectively. The differences between the two cycles are apparent, and thus they are expected to result in very different bus fuel consumptions and vehicle technical requirements.

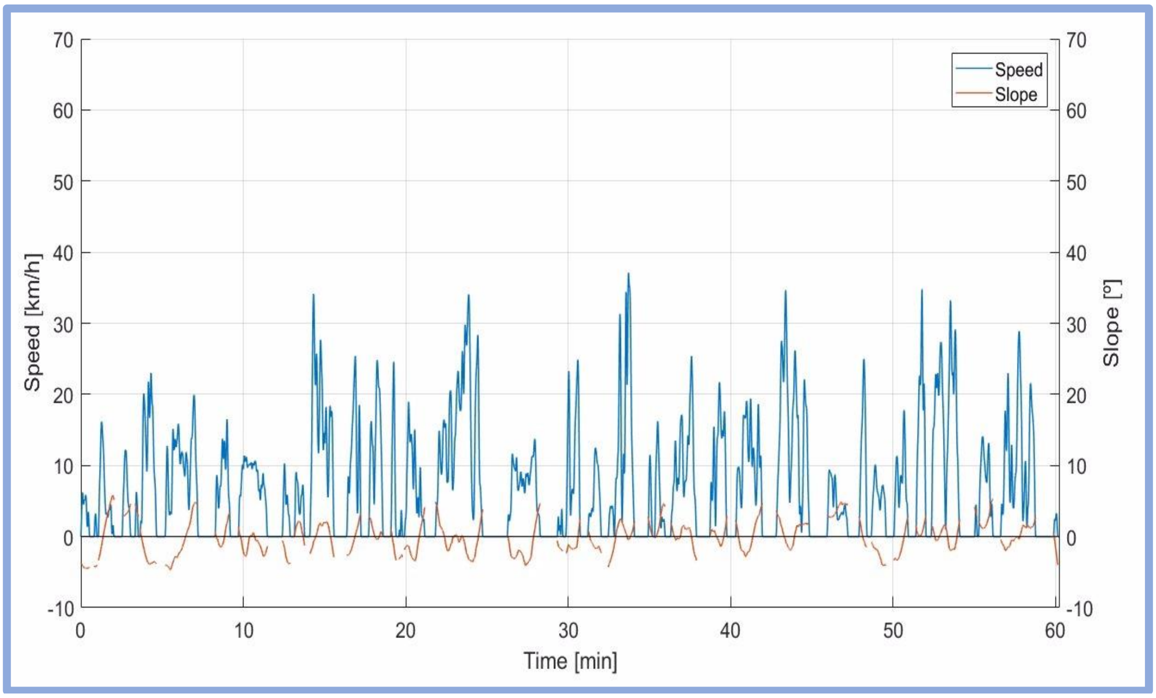


Figure 12. EBUS driving cycle. Speed [km/h] in the left axis and slope [°] in the right axis vs time in minutes is presented.

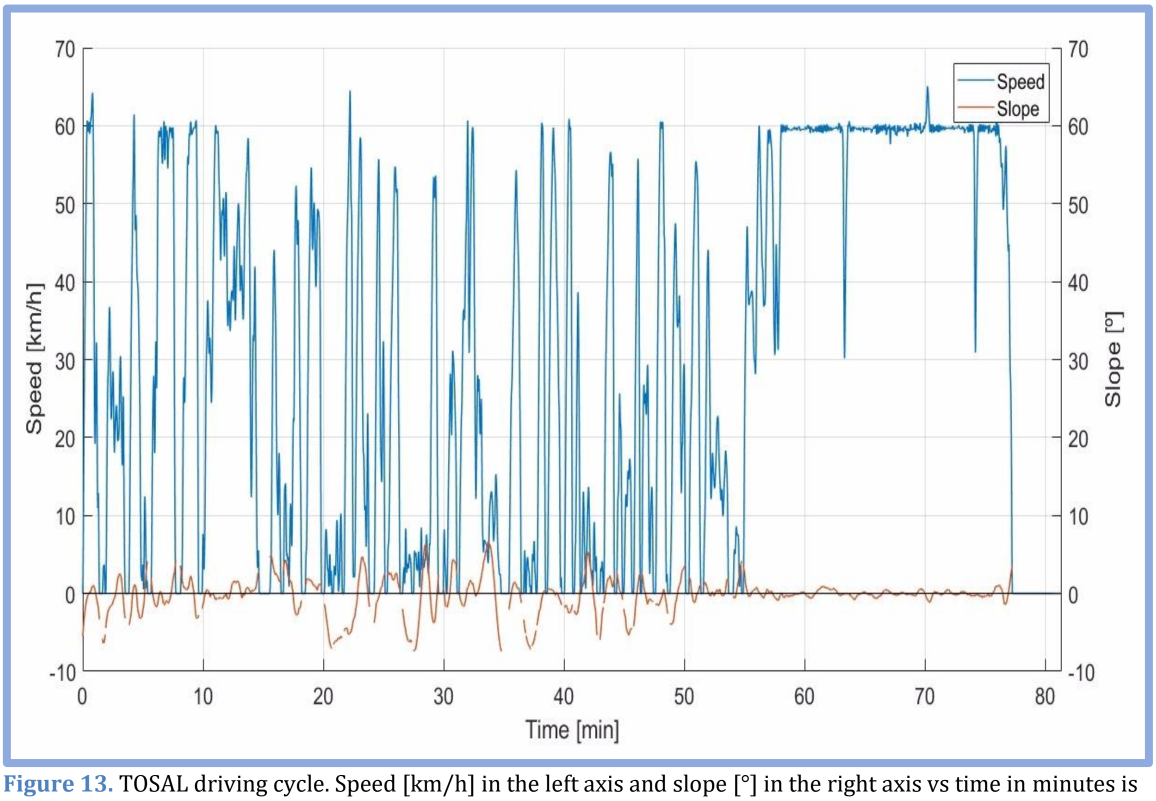


Figure 13. TOSAL driving cycle. Speed [km/h] in the left axis and slope [°] in the right axis vs time in minutes is presented.

Whilst the e-Bus has a more static operation, with a very low average speed (7.3km/h) and very long idling periods (34% of the time the bus is still), the TOLSA operation is highly dynamic with very high average speeds (32.8km/h), more aggressive pattern of acceleration (1.3 m/s2), and considerably shorter idling times (16%). This is in direct correlation with the operation of each route. Whilst the e-Bus operates in narrow one-lane urban roads, the TOLSA operation involves highways and an exclusive bus lane.

Throughout Output 2.2 the above information and that of the other evaluated bus routes will be used to assess the operation of the pertinent clean bus technologies and their techno-economic performance as well as their environmental benefits.

3.1 Electric Bus Pilot Test Preliminary Results

The e-Bus being tested is a BYD K7, 9-meter bus. **Table 5**Table shows the technical specifications of the latter. The bus operates 2 hours in the morning and 4 hours in the afternoon. It is charged during the night and again during the day between the morning and afternoon operation. Information regarding the bus operation was compiled not only by recording GPS data onboard the bus, but also by going to the bus terminal and interviewing drivers and operators in charge of the charging events of the bus (**Figure 14**).

Table 5. Technical specifications of the BYD K7 electric bus model being tested in the Casco Antiguo.

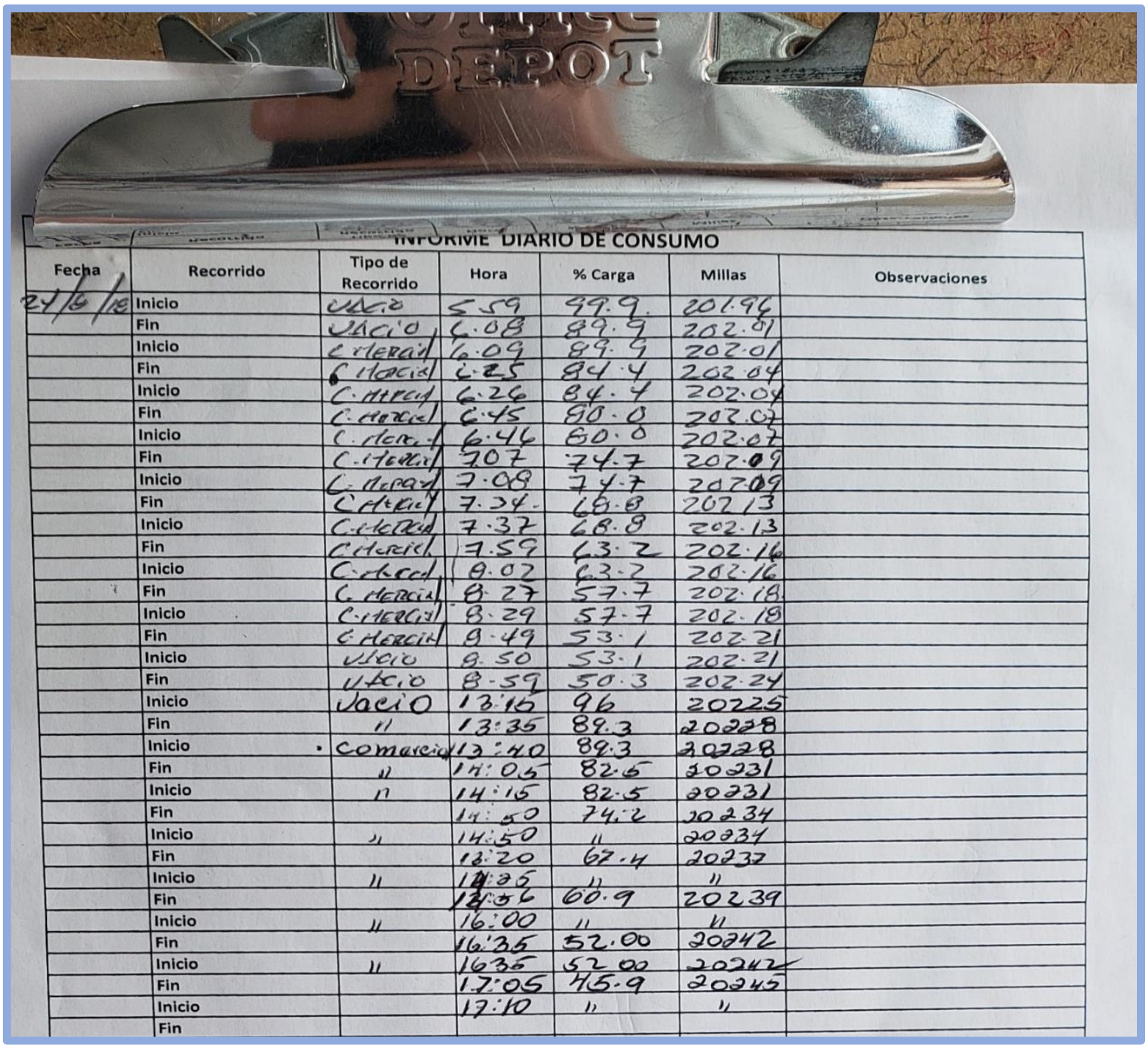
BYD K7	
Length	9.36 m
Curb weight	10,200 kg
Max. cargo	3,300 kg
Top speed	90 km/h
Max. gradeability	17 %
Max. Power	180 kW
Battery capacity	195.6 kWh
Declared range	216 km
Charging Power	80 kW
Charging time	2-3 hours

Figure 15 shows the data spread sheets filled in by the bus driver along the route on the 24th of August 2018. The information recorded in the months of August to October has been digitalized and averaged and is presented in **Table 6**.

Table 6. Electric bus pilot test preliminary results of distance traveled and energy consumption, from the 6th of August to the 17th of October.

Month	Week	Commercial distance covered [km]	Energy consumed [kWh]
August	1	183	477
	2	179	430
	3	309	767
	4	277	679
September	1	277	661
	2	256	651
	3	275	753
	4	286	640
October	1	222	535
	2	187	460

Figure 14. Some of the fieldwork of Logios team during its visit to Panama City. The top left image shows the charging process of the BYD K7 electric bus, during its daily operation. The top right image shows the interior of the e-bus during a peak-hour trip. The middle and bottom images show the end of the BYD bus journey, when the driver logs the bus operation data in the spreadsheet.



INFORME DIARIO DE CONSUMO

Fecha	Recorrido	Tipo de Recorrido	Hora	% Carga	Millas	Observaciones
24/8/18	Inicio	Vacio	5.59	99.9	201.96	
	Fin	Vacio	6.08	89.9	202.01	
	Inicio	C. Mercial	6.09	89.9	202.01	
	Fin	C. Mercial	6.25	84.4	202.04	
	Inicio	C. Mercial	6.26	84.4	202.04	
	Fin	C. Mercial	6.45	80.0	202.07	
	Inicio	C. Mercial	6.46	80.0	202.07	
	Fin	C. Mercial	7.07	74.7	202.09	
	Inicio	C. Mercial	7.08	74.7	202.09	
	Fin	C. Mercial	7.34	68.8	202.13	
	Inicio	C. Mercial	7.37	68.8	202.13	
	Fin	C. Mercial	7.59	63.2	202.16	
	Inicio	C. Mercial	8.02	63.2	202.16	
	Fin	C. Mercial	8.27	57.7	202.18	
	Inicio	C. Mercial	8.29	57.7	202.18	
	Fin	C. Mercial	8.49	53.1	202.21	
	Inicio	Vacio	8.50	53.1	202.21	
	Fin	Vacio	8.59	50.3	202.24	
	Inicio	Vacio	13:16	96	20225	
	Fin	〃	13:35	89.3	20228	
	Inicio	Comercial	13:40	89.3	20228	
	Fin	〃	14:05	82.5	20231	
	Inicio	〃	14:15	82.5	20231	
	Fin		14:50	74.2	20234	
	Inicio	〃	14:50	〃	20234	
	Fin		15:20	67.4	20237	
	Inicio	〃	15:25	〃	〃	
	Fin		15:56	60.9	20239	
	Inicio	〃	16:00	〃	〃	
	Fin		16:35	52.00	20242	
	Inicio	〃	16:35	52.00	20242	
	Fin		17:05	45.9	20245	
	Inicio		17:10	〃	〃	
	Fin					

Figure 15. Data spread sheets of the BYD K7 bus daily operation on the 24/08/2018, filled out by the bus driver along the route.

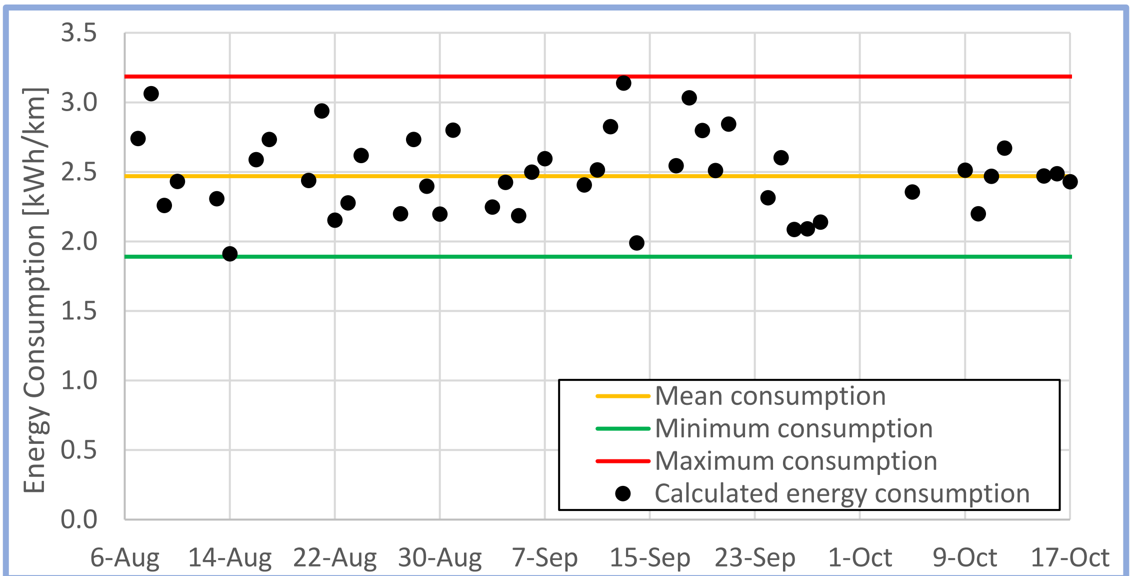


Figure 16. Daily average energy consumption of the BYD electric bus operation, calculated using the spreadsheets data filled in by the bus drivers. Information provided by MiBus.

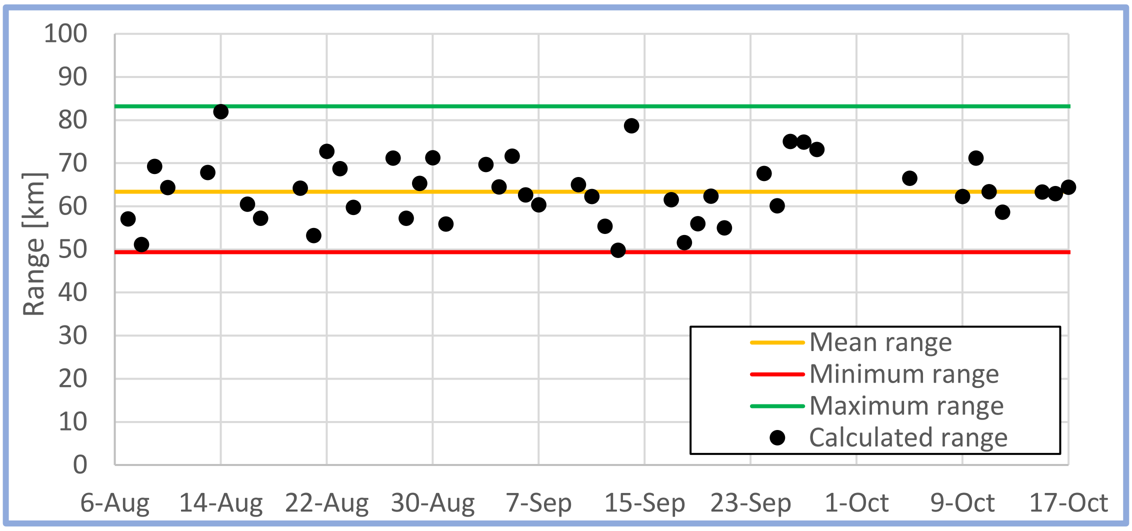


Figure 17. Operational ranges of the BYD electric bus for the different energy consumptions calculated using the spreadsheets data. The range is calculated assuming that the last 20% of the battery state of charge is not use in order to reduce battery degradation.

The first thing that is noted from the presented results is the high average energy consumption of the bus. While the data sheet of the e-bus references a range of 216 km per charge (135 miles), based on the recorded average energy consumption of 2.5 kWh/km and the 196 kWh battery pack of the vehicle, the range that the bus could attain under the evaluated operating conditions is of just 78 km. This is assuming that the battery charge is entirely depleted, which is never recommended. Normally, electric buses need to preserve the last 20% of the batteries state of charge, to hedge against battery degradation, meaning that the operational range of the bus is of just 63 km per charge.

If the bus were to provide a full day service of 16 hours, based on the recorded average speed of the current operation, it would cover at least 115 km. That distance is far in excess of the current range achieved by the system.

The main reasons for the high energy consumption per unit of distance could include the high mean slopes, the intermittency of the operation, and the intensive use of the air conditioning system (HVAC).

Having said this, throughout the following output, simulation tools will be used to evaluate the energy flow of the bus under real operating conditions to fully understand the energy profile of the system. This will yield a better understanding of why the vehicle is consuming in excess of 100% more energy than expected and will help identify potential ways to reduce this energy consumption whilst maintaining the operation requirements. Furthermore, the gathered operational data of the different routes, in addition to the use of simulation tools will allow to identify the most suitable clean bus technology for the different operations and establish a path for their implementation.

4. Summary

Throughout this output LOGIOS has undertaken an extensive fieldwork evaluation of the public bus operation of Panama City. This involved the compilation of real driving bus operation profiles for eight different bus routes using GPS data accusation systems, as well as interviewing the system drivers, operators, and management staff.

The acquired data was then used to establish driving profiles for the different routes, which will be used in the following section of Output 2 as inputs to the vehicle simulation tools that will assess the performance of various bus technologies over the different bus operating conditions.

Overall, the evaluated routes show a good spread of operating parameters with mean speeds ranging from 7 to 33 km/h, positive accelerations from 1 to 1.5 m/s^2, and idling times from 15% to 35%.

Regarding the operation of the e-bus being tested in the Casco Antiguo, energy consumption records show a considerably higher energy consumption per km than expected. This is thought to be mainly due to the use of the HVAC system, which is most likely operating at full capacity all the time. Throughout the following output, simulation tools will be used to evaluate the energy flow of the bus under real operating conditions to better understand the energy profile of the system. Furthermore, the gathered operational data of the different routes, in addition to the use of simulation tools, will allow LOGIOS to identify the most suitable clean bus technology for the different operations and establish a path for their implementation.

5. Annex

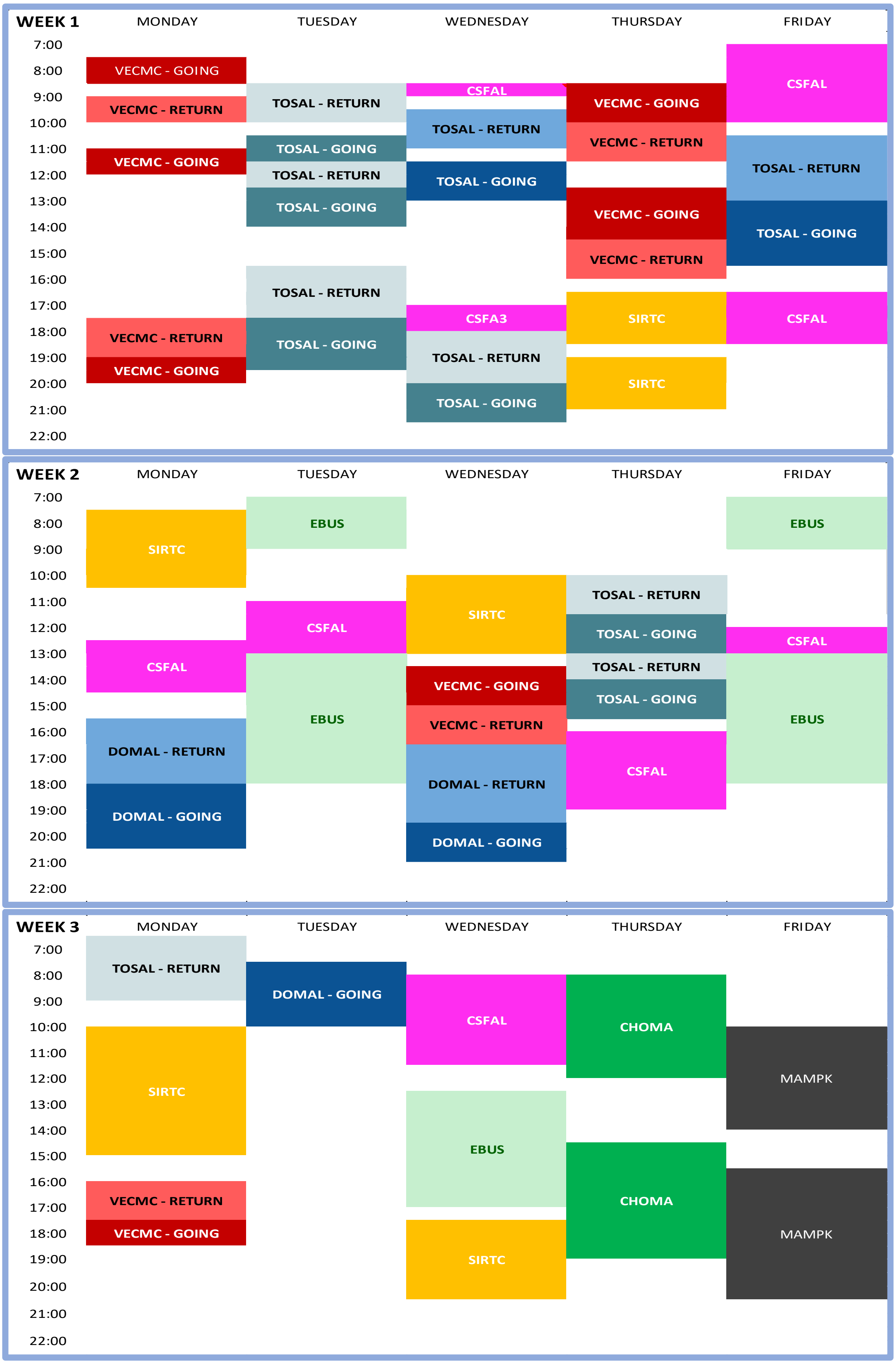


Figure A1. Data collection chronogram of the different selected routes throughout LOGIOS visit to Panama City.